Method for Constructing EMI Shielding around a Component Embedded in a Circuit Board

The present invention relates to a method, according to the preamble of claim 1, for constructing EMI shielding around a component to be embedded in a circuit board. The invention also relates to a circuit board according to the preamble to claim 15.

Patent publication US 6,388,205 B1 discloses the shielding of an electric circuit that is partly or entirely embedded inside a circuit board, using a unified metal shield, which surrounds the electric circuit from all sides, without openings, except at the points at which the electric circuit is connected to another electric circuit.

Patent application publication US 2003/0188889 A1 discloses an electric circuit, in which the signal conductor is surrounded by several electrically conductive openings, which openings are lined with an electrically conductive layer. Thus the construction is more durable and flexible compared to a unified construction and also cheaper and faster to manufacture.

Patent application publication WO 03/065778 discloses a semiconductor component embedded in a circuit board, which is covered by an insulation layer on at least one side of the base and in which the side walls of the hole made for the component are lined with a conductive material.

International patent application publications WO 00/14771 and WO 00/16443 disclose a method for making EMI-shielded conductor grooves in a circuit board, in which the conductor groove is embedded in insulation between two conductive layers and is shielded laterally by trenches, which are lined in an electrically conductive manner, so that they form a coaxial line.

Patent publication US 6,131,269 discloses the construction of a module, in which the components are embedded on a dielectric substrate under which there is a metal layer. Between the components extending all the way through the dielectric substrate to the

metal layer is installed a metal isolation wall. The components are embedded to the dielectric substrate during the module construction.

Patent publication US 5,987,732 discloses the construction of a multi layer integrated microwave assembly. A light resist layer is deposited on the substrate, a portion of which is selectively removed and a first conductive layer is applied. A second portion of the light resist layer is removed leaving isolation walls and cavities. Electrical components are placed in the cavities and a first dielectric layer fills the cavities. On this layer is applied a second conductive layer, a portion of which is removed. Electrical connections are created from conductive layers to others through the dielectric layer. For the first dielectric layer is used liquid material, polyimide, which is cured at 250 °C.

Patent publication JP 2000183488 discloses a circuit board, in which the component is mounted to a recess, a metallic film is formed on the wall of the recess. There is no insulating material around the component.

Patent application publication JP 2002-16-16 327 discloses a component embedded in a hole drilled in a base, in which a conductive material is grown on the side walls of the hole.

The present invention is intended to create EMI-shielding structures inside a circuit board, in such a way that active components, circuits, or modules can be embedded in the circuit board.

The invention is based on the idea that a recess is made in the circuit board, around the location in which the component is embedded, which essentially surrounds the component, and the recess is surfaced or filled with an electrically conductive material, in such a way that the surfaced or filled recess forms a bezel around the component, which shields the component, at least from electromagnetic radiation arriving laterally at the circuit board. An insulating layer, which insulates the component and the bezel from each other, is preferably formed between the bezel and the embedding opening of the component.

More specifically, the method according to the invention is characterized by what is stated in the characterizing portion of claim 1.

The construction according to the invention is, in turn, characterized by what is stated in the characterizing portion of claim 15.

Considerable advantages are gained with the aid of the invention. The method permits EMI shielding to be built into the circuit board around the component being embedded. The construction is analogous to a metallic shield casing, but in this case the component is shielded by an electrically conductive bezel, which can be of metal, conductive polymer, conductive glue, or some other material blocking electromagnetic radiation, made inside the circuit board. The recess extends to the conductive layer of the circuit board that represents the ground-reference plane, so that the material is brought into electrical contact with the ground-reference plane.

Making the shielding EMI structure inside the circuit board allows sensitive active or passive components, circuits, or modules to be embedded without casing, because the internal EMI shield protects the components from both external interference signals and those coming from inside the circuit board.

The advantageousness of the construction is also added to by the fact that the shape of the shield structure can be influenced during the manufacturing stage of the structure. If desired, the shield structure can be constructed to surround the component being embedded in the circuit board from all sides, without an opening, or in such a way that the shield is open on some side, though it does, however, substantially surround the component. The construction also has the advantage that the recess can, in some embodiments, also be surfaced or filled with an electrically conductive material that is flexible, translucent, and/or is transparent.

A further advantage of the construction is that, the component can be embedded to the circuit board at any stage during construction of the circuit board or afterwards, which

has the advantage that the component is not exposed to conditions which are unsuitable for the component, such as high temperature and pressure.

By selecting the materials of the circuit board and shield structure to complement each other, so that together they will provide the circuit board with, for example, flexibility, transparency, or some other desired property, circuit boards can be given new properties, thus permitting their possible applications to be expanded.

The preferred embodiments of the invention offer advantages over solutions, in which the bezels of the embedding hole of the are lined with metal, because, according to the embodiments, the separation of the component from the EMI shield is better ensured In the embodiments, conducting material need not be brought into the installation hole of the component, in order to manufacture the EMI shield. In addition, there is greater freedom in the selection of the conducting material of the EMI shield.

The preferred embodiments of the invention also offer advantages over the solutions disclosed in patent publication US 6,388,205 B1. In the solutions of the patent publications, the EMI shield must be manufactured in connection with the manufacture of the layers of the circuit board, so that in practice the conducting material of the circuit board must always be chosen as the material of the EMI shield. In preferred embodiments of the present invention, the EMI shield is constructed in a finished, or semi-finished circuit board.

In the solutions disclosed in patent publications WO 14771 and WO 16443, the conductor grooves are shielded in the lateral direction of the circuit board using long trenches lined with an electrically conductive material, which give the circuit board a rigid structure and reduce its durability.

Patent application publication US 2003/0188889 A1 discloses that considerable advantages can be obtained by forming the EMI shield from conductors made in separate holes, instead of a continuous wall. Therefore, the construction disclosed in the US patent application is cheaper and faster to create. In addition, the separate conductors

do not reduce the mechanical durability of the circuit board, nor do they also reduce the flexibility of the board in the same way as continuous walls do. In the preferred embodiments of the present invention, flexible materials, such as conductive polymers and conductive glues are used to construct the shielding structure, instead of metals, and thus retain the flexibility of the circuit board, without sacrificing durability. By using conductive polymers or conductive glues, the circuit board can gain other beneficial properties too, such as transparency. A continuous groove is also easier to fill with polymer. In the preferred embodiments of the present invention, the location of the holes need not also be planned separately, as must be done in the solutions according to the US patent application publications.

The invention has many preferred embodiments. By using the method according to the invention, it impossible to embed active or passive components, or EMI-sensitive structures in general, in a circuit board. RF-circuits, for example, can be buried with the aid of the embodiments.

The present construction is suitable, in particular, embedding optoelectronic components to a circuit board. In methods for constructing circuit boards, in which the component is embedded to the insulating layer during the construction of the circuit board, as in US 6,131,269, the component should resist high temperatures and pressures, which are used during precuring and thermocompressing. In the present invention the component is embedded to a multi layer circuit board afterwards, the component being thereby not exposed to the conditions needed during construction of the circuit board. There is preferably optical material, such as air, surrounding the optoelectronic component. In patent publication US 5,987,732, between the shielding walls there is used liquid material, which should be cured in 250 °C. Most optic components would not resist this temperature.

With the aid of embodiments according to the preferred embodiments, it is also possible to transfer heat outside of the circuit board, particularly to beneath it, with the aid of a conductive material, for example, by using a metal, glue, or polymer that conducts both heat and electricity.

In the following, the invention is examined in greater detail with the aid of examples of applications and with reference to the accompanying drawings. The examples of applications are in no way intended to restrict the scope of the protection defined by the claims.

Figure 1 shows a cross-section of the basic construction of a circuit board according to the invention.

Figure 2 shows a cross-section of one circuit board according to the invention, at the feed-through for a component.

Figure 3 shows a cross-section of the recesses drilled into the circuit board.

Figure 4 shows a cross-section of the filling of the recesses drilled into the circuit board.

Figure 5 shows a cross-section of the removal of the insulation layer at the embedding location of the component in the circuit board.

Figure 6 shows a cross-section of the attachment of the component at the embedding location.

Figure 7 shows a top view of one component of the circuit board, together with its shielding structures.

In connection with the present invention, the term 'circuit board' refers to a multi-layer circuit board, in which there is not only a conductor layer forming the ground-reference plane, i.e. the 0 level, but also at least two conductor layers, which are typically electrically conductive signal layers. The conductor layer is of some electrically conductive metal, usually copper. The conductor layers are separated from each other by an insulating layer.

A 'component' is typically a semiconductor component, for example, an optoelectronic component or a microcircuit or passive component, such as an integrated passive component. Semiconductor components are usually silicon or gallium-based components, to which small amounts of phosphor, boron, or other alloy atoms are added, in order to alter the electrical properties of the semiconductor.

The term 'ground-reference plane' refers to a conductive layer, which is grounded or connected to another 0 potential, for example, to the floating 0 potential of the circuit.

The term 'above the ground-reference plane' refers to that side of the circuit board, to which the components are attached. The term 'below the ground-reference plane' refers to the opposite side of the board.

Between the conductive layers there is insulating material, which can be plastic or epoxy or some similar material. The insulating material is a material, which does not act as an electrical transmission path. The insulating material can be selected, for example, from the group: various resins, epoxy glass, polyimide (e.g., Dupont KAPTON), polyimide-quartz, polyester, acryl, bismaleimide triazine, glass-fibre, cyanate-ester glass, XPC (paper phenol), FR-1 (paper material with a phenolic binder), FR-2 (paper material with a phenolic binder, UL94-V0), FR-3 (paper material with epoxy resin), FR-4 (glass-fibre-epoxy laminate), CEM (composite epoxy material), CEM-1 (paper-based laminate, with one layer (7628) of woven glass-fibre), CEM-3 (glass epoxy), aromatic polyamide (aramide fibre, e.g., Dupont Kevlar, Epoxy-Kevlar, or Nobel's Twaron), PTFE (Teflon), benzocyclobutene, micro-fibre laminate, and Bakelite.

Special bases can be aluminium in general, LTCC (low-temperate co-fired ceramics), HTCC (high-temperature co-fired ceramics), glass, quartz/silicon dioxide, AlN, SIC, silicon, BeO, and BN.

Plastics, which can be used as the insulating material in a circuit board include: polyethene, polypropene, polybutene, polymethylpentene, polyamides, polyimide, polysulphone, polyether ether ketone (e.g., PALAP developed by Denso Corp. and

Mitsubishi Plastics Inc.), polyvinylchloride, styrene plastics, cellulose plastics, polymethylmetacrylate (PMMA), polyacrylnitrile, polycarbonate, polyethene-terephtalate, and fluor plastics.

Electrically conductive polymers and glues can be divided into thermosetting polymers and thermoplastic polymers. In order to increase conductivity it is possible to use fillers such as silver, gold, or nickel.

Conductive polymers include: polyacetylene, polythiophene, polypyrole, poly(p-phenylenevinylene), polyaniline, poly(2,3ethyldioxitiophene).

Conductive glue is generally formed form three main components: a conductive filler, a polymer, e.g., epoxy, modified epoxy or silicone, and e.g. an agent/agents providing an antistatic property. Curing/drying takes place using UV light or heat, depending on the glue used. Certain glues will cure even at room temperature.

Commercial (one or two-component) electrically conductive isotropic glues include:

Emerson & Cuming
Ablebond 976-1, flexible, electrically conductive adhesive, filler silver
Ablebond 84-1LMI NB, electrically conductive epoxy adhesive, filler silver
Eccobond 57 C, electrically conductive epoxy adhesive, filler silver
Eccobond 50298 two-component electrically conductive epoxy adhesive, filler nickel
AMICON C 850-6 epoxy adhesive, filler silver
AMICON CE 8500 electrically conductive modified epoxy adhesive, filler silver

Northrop Grumman Corporation
SE-CURE 9502 electrically conductive adhesive, filler silver

Loctite
Product 3880 electrically conductive epoxy adhesive, filler silver (particularly for attaching EMI components)

Product 3888 epoxy adhesive, filler silver

Product 5420 electrically conductive silicone

Product 5421 RTV silicone (provides EMI/RFI shielding)

Dow Corning

DA 6524 electrically conductive silicone adhesive

DA 6533 electrically and thermally conductive silicone adhesive

Panacol-Elosol Gmbh

Elecolit 312 LV (solvent-free epoxy adhesive, filler silver)

Elecolit 323 (conductive epoxy adhesive, filler silver)

Elecolit 342 (conductive acrylate adhesive, filler silver)

Elecolit X-160378 (conductive epoxy adhesive, filler silver)

Commercial (one or two-component) electrically conductive anisotropic glues include:

Loctite

Product 3441 (epoxy adhesive, gold-surfaced polymer)

Product 3446 (epoxy adhesive, fusing filler)

Product 3440 (filler gold polymer)

Product 3445 (fusing solder filler)

Telephus

AcpMat series (epoxy-based adhesive resin paste, with a conductive filler and other special fillers)

Figure 1 shows a cross-section of the basic construction of one circuit board. In connection with the manufacture of the circuit board, alternating conductive layers 1, 3 and insulating layers 2 are built on the circuit board. One layer of the conductive layers corresponds to the ground-reference plane 3, i.e. the 0 plane. In this example of a circuit board, there are at least three conductive layers: a ground-reference plane and a signal layer above and below it. Typically, there are 2 - 4 signal layers above and below the

ground-reference plane.

Figure 2 shows a cross-section of the circuit board of Figure 1, at an embedding hole for a component. In the circuit board, the conductive layers 1 and the insulating layers 2 alternate. One of the conducive layers is the ground-reference plane 3. To make it easier to embed the component inside the circuit board, an area, which is free of conductive layers and thus contains only insulating material 2, on at least one side, i.e. the side of the embedding location of the component, is built at the embedding location of the component. In the embodiment, which is shown in Figure 2, an opening 4 is left in the ground-reference plane at the embedding location. In the manufacturing stage, a continuous or discontinuous metal layer 5, which is formed from the material of the layer 3, e.g., copper, can be left at this opening. The insulating material 2 is left in the openings.

If it is wished to bring the component into electrical contact with the conductive layer 1 beneath the ground-reference plane, prior to the manufacture of the metal layer 5, it is best to make a feed-through 14 using some suitable feed-through method, for example, the micro-via method, through the insulating layer 2 below the ground-reference plane 3, to the conductive layer located beneath. The feed-through 14 is of some electrically conductive material, such as a metal.

Figure 3 shows a cross-section of the recess 6 drilled in the circuit board of Figure 1 and 2. Using a selective laser drill or a corresponding method, the recess 6, which extends to the ground-reference plane 3, is cut around the embedding location of the component. The ground-reference plane should preferably be under the entire area in which the drilling takes place, to make it easier to control the depth of the drilling. There are preferably no signal connections 1 in the area of the cutting, so that the depth can be controlled with the aid of the ground-reference plane 3 and so that the signal leads will not connect to the ground-reference plane 3 through the EMI shield. For example, selective laser drilling does not eat into the metal, but only the insulating layer, so that cutting will stop when it meets the ground-reference plane 3.

Figure 4 shows a cross-section of the filling of the recess drilled into the circuit board of Figures 1 - 3. In one embodiment, after drilling the recess is metallized with an electrically conductive metal. Metallization takes place in such a way that, as a first stage, a seed layer 8 of the selected metal, e.g. copper, is grown chemically in the recess, after which the final metal layer 9 is grown electrochemically. The recess can be filled partly, i.e. only surfaced with metal, or else the recess can be filled completely. Alternatively, the recess can be filled or surfaced with a conductive polymer or conductive glue. When using a conductive polymer or glue, the layers 8 and 9 can be of the same or a different conductive polymer or glue. When using a conductive polymer or glue, the filling need not necessarily take place in layers, instead the filling or surfacing of the recess can take at one time. The recess surfaced or filled with an electrically conductive material forms a structure shielding against electromagnetic radiation, which in this case is referred to as a bezel 10.

Figure 5 shows a cross-section of the removal of the insulating layer 2 at the embedding location of the component in the circuit board of Figures 1 - 4. After making the EMI bezel, a hole 11 is made for the components to be embedded, for example, by selective laser drilling, to the level of the ground-reference plane 3, inside the recess 6 (or bezel 10). A bezel 7 of insulating material 2 is left between the component being embedded and the recess. A continuous or discontinuous metal layer can be left to the depth of the ground-reference plane in the manufacturing stage of the circuit board. If drilling is carried out by selective laser drilling, or a similar method, the drilling will stop at the metal level. This allows the depth of the embedding of the component being embedded to be controlled and adjusted.

Naturally, drilling can also take place in the opposite order, i.e. first of all the hole at the embedding location of the component is drilled and only after that the recesses around the embedding location. In both cases, an insulating layer 7 is left between the recess and the embedding location of the component. It should be noted, however, that when the recess is to be filled with metal, it is generally preferable to make and fill the recesses first, so that the metal will not enter the hole 11 made for the component. If the recess is filled with a conductive polymer or conductive glue, both the recess and the

opening for the component can be drilled and filled in any order whatever, or simultaneously. Because the conductive polymer or glue can spatter, it may therefore be preferable to manufacture and fill the recesses first of all.

Figure 6 shows a cross-section of the component being embedded in place in the circuit board of Figures 1 - 5. The component 12 is attached to its contact base, for example, isotropically or anisotropically, using a glue or solder or a conductive polymer, which has a sufficiently great conductivity. In the embodiment of Figure 6, the component is attached, with the aid of conductive glue 13, to the metal layer 5. The electrical connection from the component 12 to the conductive conductor layer 1 located below it is implemented through the insulating layer 2, using some feed-through method, for example, the micro-via method (micro-via 14), as has been described above. The conductor layer 1 beneath the ground-reference plane can also be built only after the electrical connections have been made through the insulating layer 2 beneath the ground-reference plane 3. Alternatively, the conductive layer beneath the ground-reference plane can be finished and the connections made through it.

Heat can be transferred from the component to outside the circuit board, particularly to beneath it, or to the entire casing structure, with the aid of a conductive material, for example, a thermally and electrically conductive metal, glue, or polymer.

As described above, the electrical connections can be made to the conductor layer situated below the ground-reference plane using some feed-through method. Alternatively, the connection, or some of the connections can be made to the conductor layer situated above the ground-reference plane, for example, with the aid of bonding (for instance, wire bonding using gold or aluminium wire).

After the embedding of the component 12, the empty hole 11 remaining around the component can be left empty or alternatively filled with some suitable filler material.

If required, the component can be shielded from above, i.e. from the side of the component opposite to the attachment point, for example, with the aid of an electrically

conductive sticker.

Figure 7 shows a top view of one component, together with its shield structure, of the circuit board of Figures 1 - 6. The filled recess surrounding the component 12 forms a bezel 10, which shields the component from electromagnetic radiation coming from at least the direction of the circuit board. An insulating layer 7 remains between the component 12 and the bezel 10, while insulating material 2 can be seen between it and the component 12.